BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: Preliminary Thoughts on Cryogenic Servicing of the 16-Day CSM - Case 320

DATE: August 11, 1969

FROM: G. J. McPherson Jr.

ABSTRACT

The modifications which will provide the Block II CSM with a 16-day operational lifetime to support the Apollo Lunar Exploration Missions (ALEM's) includes provision for additional cryogenic storage vessels in the Service Module. This memorandum addresses some preliminary thoughts, pertinent considerations, and current actions associated with providing a capability for servicing the expanded cryogenic storage system.

Included are a description of the SM configuration, the current servicing GSE configuration, four basic candidate servicing configurations, and the apparent advantages/disadvantages of the candidate configurations.

It is recommended that consideration be given to providing the servicing GSE with the features offered by one of the candidate configurations discussed. Also that the design provide for maximum reliability and flexibility without extending servicing timelines.

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SUBJECT: Preliminary Thoughts on Cryogenic Servicing of the 16-Day CSM - Case 320

DATE: August 11, 1969

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MEMORANDUM FOR FILE

The modifications which will provide the Block II CSM with a 16-day operational lifetime to support the Apollo Lunar Exploration Missions (ALEM's) includes provision for additional cryogenic storage vessels in the SM. Figure 1 provides an overall view of the major ALEM CSM modifications including the add-on storage vessels and associated panels for control and display functions. This memorandum addresses some preliminary thoughts, pertinent considerations, and current actions associated with providing a capability for servicing the expanded cryogenic storage system.

A. ANTICIPATED CONFIGURATION OF CSM

The present CSM cryogenic storage system consists of two Block II liquid hydrogen (LH_2) storage vessels, two Block II liquid oxygen (LO_2) storage vessels, two dual modularized control boxes (filters, check valves, pressure transducers, pressure switches, etc.), control panels in the CM, servicing disconnects, and related plumbing/electrical harnessing. The add-on storage system, which will utilize off-the-shelf hardware to the maximum extent possible, will consist of an additional Block II LH_2 storage vessel, an additional Block II LO_2 storage vessel, two dual modularized control boxes (only half of each will be used), an additional control panel in the CM, separate servicing disconnects except for the hydrogen relief function, and additional plumbing/electrical harnessing.

The relationship between the location of existing and add-on storage vessels and servicing disconnects is shown in Figure 2. It should be noted that the existing and add-on storage vessels and servicing disconnects are 180° removed from each other. The add-on LH_2 and LO_2 storage vessels will be mounted above and below, respectively, on a new common shelf at the forward end of SM Bay 1. The remainder of Bay 1 will house the Scientific Instrument Module (SIM) as shown in Figures 1 and 2.

A preliminary plumbing schematic for the expanded LO_2 storage system is reflected in Figure 3 (LH_2 system is identical except as noted). For simplification, only major components are shown.

B. PRELIMINARY THOUGHTS ON SERVICING

The existing LH_2 and LO_2 storage systems are serviced via portable dewar units. These are located on MSS Platform 4A (one at a time) during servicing operations*. At present, a single LH_2 or LO_2 dewar unit has sufficient capacity to provide full mission load to its respective system. Single dewars, however, will not be able to supply full mission load to the expanded storage system (see Table 1).

In consideration of the foregoing fact, along with the desire to utilize the existing servicing GSE hardware to whatever extent possible, the following four basic candidate configurations have evolved:

Note: Figures and discussions are typical for both the. LH_2 and LO_2 storage systems.

1. use existing valve box and provide new flexline for servicing the add-on storage system--servicing of the existing and add-on systems would be accomplished serially--one dewar exchange would be required (see Figure 4a)

2. modify valve box to accommodate additional flexline and associated valving for servicing the add-on storage system--servicing of the systems would be accomplished concurrently--one dewar exchange would be required (see Figure 4b).

3. modify valve box to accommodate a second dewar unit, additional flexline, and associated valving for servicing the add-on storage system--servicing of the systems would be accomplished individually but concurrently--no dewar exchange required (see Figure 4c).

*Fully serviced backup dewars are held in readiness at the launch pad in the event a primary dewar fails or does not supply adequate mission load.

4. modify valve box to accommodate hardware described in 3 above and to manifold both the dewar inputs and valve box outputs for maximum flexibility and reliability--servicing of the systems would be concurrently and in parallel--no dewar exchange required (see Figure 4d).

C. PERTINENT CONSIDERATIONS

Many factors will no doubt influence the decision on which GSE configuration should be pursued. Those felt to be of prime importance follow:

1. Servicing timelines - Much effort has been expended toward building a workable-efficient countdown. Any significant extension of or pertubation to SM cryogenic servicing timelines will produce undesirable effects on the space vehicle countdown operation. Most notable would be the necessity to accomplish prior countdown operations farther away from scheduled T-0 and the major rework of numerous KSC procedures. Additionally, critical scrub-turnaround capabilities would be adversely affected by extended servicing timelines. Candidate configurations 1 and 2 would be eliminated under the timeline criteria alone.

2. System reliability/flexibility - Since countdown and scrub-turnaround operations demand both reliability and flexibility to whatever extent possible, both should be considered in selecting a design for the servicing GSE. Both candidate configurations 3 and 4 would appear to have comparable reliability but the latter has considerable increased flexibility since failure of a single dewar unit would not interrupt servicing but only extend it, dependent upon when the failure occurs.

3. MSS platform structural limits - A single LO_2 dewar unit when fully loaded weighs about 1460 pounds. Since numerous other equipments as well as personnel will account for additional weight to be supported by the MSS platform, an assessment will be necessary to determine if two fully loaded dewars can be accommodated. If not, alternate techniques such as partially loaded dewars (would need about 65% in each dewar to supply required mission load), removal of other equipment, limitations on numbers of personnel on the platform when dewars are present, beef-up of platform, etc., could be implemented. Both candidate configurations 3 and 4 could accommodate the partially loaded

dewar technique. In the first case, the loads would necessarily be 100% and 50% while in the latter they could be 65% and 65% or any other desired combination which provides adequate mission load. Consideration of a single-larger dewar can be eliminated because of weight and size constraints levied by both MSS platform and MSS elevator capabilities.

4. Hardware availability/cost - It would appear that the only significant new hardware involved would be procurement of additional dewars. The valve box and plumbing modifications could most likely be assembled largely from spare parts with limited "new buys." Assuming the additional dewars would be required to provide a ready backup regardless of the configuration selected, none of the candidate configurations seem to require significantly more or less modification than the other.

5. Compatibility with existing FDS - An assessment would necessarily be made to determine if any of the configurations could not be easily accommodated by the existing Fluid Distribution System (FDS). Since the dewars interface with the FDS for functions such as purge gas supply, venting, power, etc., it must be ascertained whether or not line sizes, flow rates, etc., can handle a dual dewar operation without unduly penalizing servicing timelines.

6. Operational/safety aspects - Dependent upon the configuration chosen and the location of attended equipment, a manloading review may be required. An operation involving two dewar units located far enough apart to satisfy platform structural constraints may establish the need for additional operating personnel. This would then necessitate review from an availability aspect (Are additional-properly trained personnel readily available?), from a weight standpoint (Will the increased number of operating personnel violate the MSS platform structural constraints?), and from a safety standpoint (Manloading is tightly controlled for hazardous operations). Additionally, an operation involving two dewars would require an assessment from an operational safety viewpoint.

D. CURRENT ACTIONS

KSC is currently studying various servicing options for the expanded cryogenic system. One of their prime objectives is to maintain and, if possible, improve the existing servicing timelines for both countdown and scrub-turnaround operations. Study completion is targeted for late August. Preliminary indications are that a two dewar configuration will be employed. The study will also address itself toward identifying additional modifications required to delete/remove other FDS GSE outmoded by the existing dewar loading technique.

NAR Downey is currently firming up their conceptual design for the onboard CSM modifications. The ALEM CSM Preliminary Design Review (PDR) is scheduled for August 13, 1969.

E. ADDITIONAL ITEMS OF INTEREST

1. The add-on cryogenic system will be utilized to supply the majority of fuel cell and ECS expendables for the initial phase of the mission commencing with the earth orbit event.

2. The add-on system will not interface with the caution and warning system (possible because of 1. above).

3. No provision will be made to activate the add-on storage vessel heaters from the airborne source. Fan operation will provide enough heat along with tank heat-leak to maintain system operation.

4. KSC has procured addtiional LH_2 (modified SHe) and LO_2 dewar units which are presently being outfitted for use in support of servicing the SM expanded cryogenic storage system. This brings the total number of dewars to three each and will allow retention of the "backup" capability in the event of a dewar failure.

5. Pertinent statistics on dewar and CSM cryogenic storage system capacities are provided in Table 1.

F. ADVANTAGES OF DUAL DEWAR/MANIFOLDED CONFIGURATION

1. offers timeline consistent with existing timelines; might even improve them.

2. partial dewar loading is entirely flexible (65% each, 100% - 30%, or any combination adequate to obtain mission load in the event that MSS platform structural constraints will not allow use of two fully loaded dewars.

3. servicing delays due to a dewar failure would be eliminated or at least minimized since:

a. the second dewar can continue servicing while the failed unit is replaced by the backup dewar; also eliminates need for re-chill down of lines when the backup dewar is brought into service (might require small bleed valves just upstream of manifold).

b. failures after partial mission load is aboard might allow the second dewar to complete servicing without need of the backup dewar (this technique would be greatly enhanced if the MSS platform will accommodate two fully loaded dewars).

4. can be implemented as a single servicing operation unlike candidate configuration 3 which in reality is two separate servicing operations being performed in parallel.

G. CONCLUSIONS

Numerous possibilities exist for selecting a GSE configuration to service the ALEM CSM expanded cryogenic storage system. The dual dewar/manifolded technique of candidate configuration No. 4 is the only one discussed which offers both the desired efficiency and flexibility assuming MSS platform structural constraints can be satisfied.

H. RECOMMENDED ITEMS FOR FURTHER CONSIDERATION

1. That a GSE servicing configuration with features similar to that of candidate configuration No. 4 be considered for the advantages discussed herein.

2. That the design, if feasible, provide the flexibility to exchange a failed dewar while continuing the servicing operation with the other.

3. That the location of the dewars onthe MSS platform be chosen to accommodate fully loaded dewars (and exchange of failed dewars) as well as the necessary numbers of operating personnel.

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Attachments
Figures 1 - 4
Table 1

REFERENCES

1. GSE Functional Integrated Systems Schematics Block II S/C Pad-MSS LC 39-KSC, North American Rockwell, Inc., G34-909102 Rev. L, dated June 6, 1969.

2. Integrated Systems Schematic; Apollo CSM; CSM 104, 106 and subs, North American Rockwell, Inc., V34-900101 Rev. P, dated March 14, 1969.

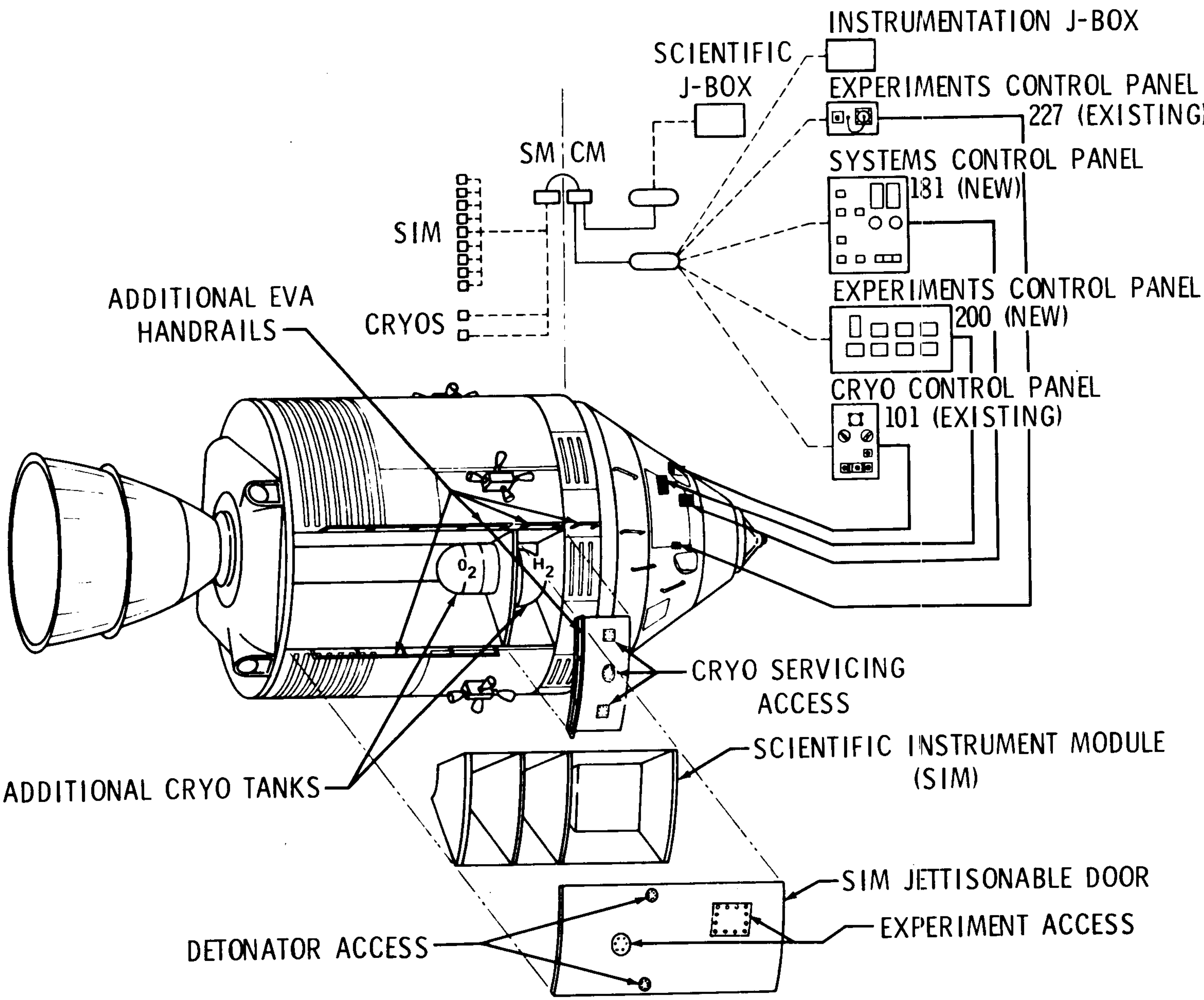
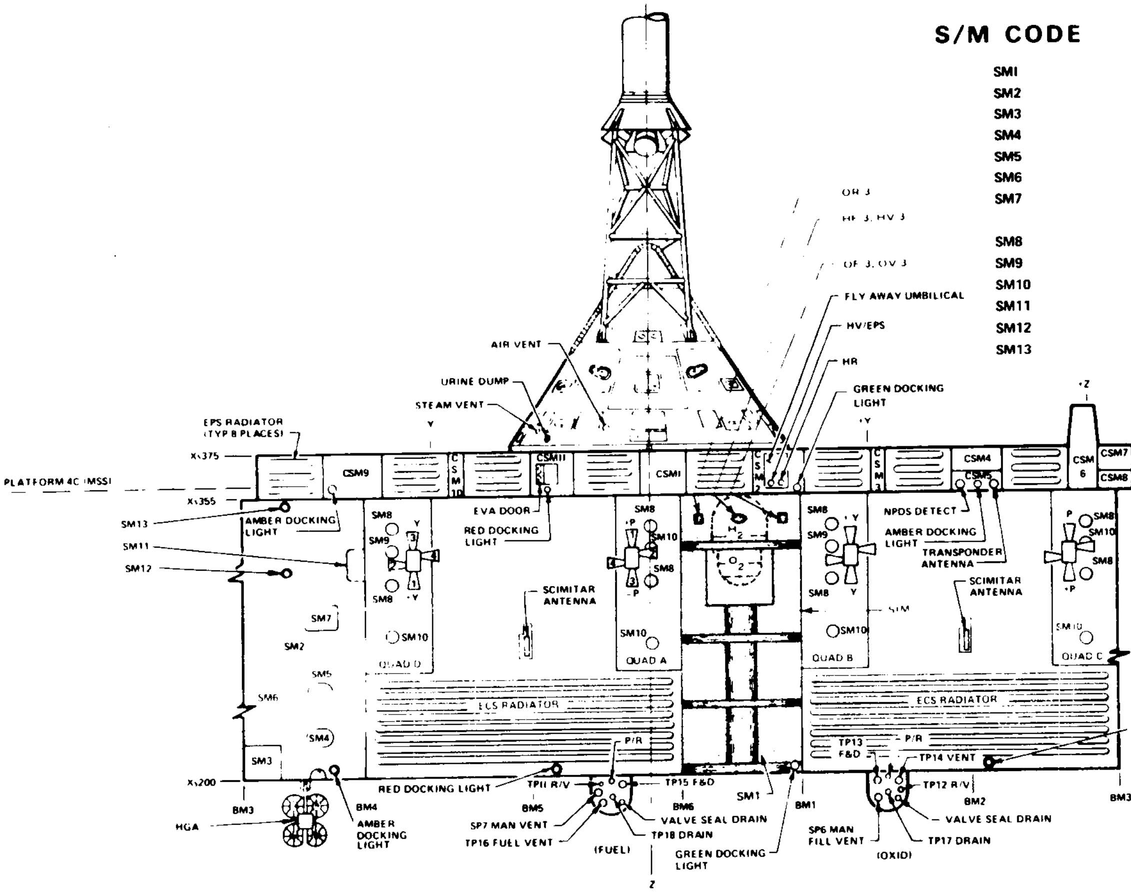


FIGURE 1 - ALEM CSM MODIFICATIONS

S/M CODE	ACCESS TO:
SMI	BAY 1
SM2	FUEL CELLS & CRYO TANKS
SM3	He SERVICING (SPS)
SM4	HF-2 (TK2 LH_2 FILL) & HV-2 (TK2 LH_2 VENT)
SM5	HF-1 (TK1 LH_2 FILL) & HV-1 (TK1 LH_2 VENT)
SM6	HP (GSE GH_2 SUPPLY)
SM7	OR (TK GO_2 RELIEF), OP(GSE GO_2 SUPPLY) OF-1 (TK1 LO_2 FILL), OV-1 (TK1 LO_2 VENT), OF-2 (TK2 LO_2 FILL) & OV-2 (TK2 LO_2 VENT)
SM8	QUAD SERVICING
SM9	QUAD SERVICING
SM10	QUAD SERVICING
SM11	W/G F&D, FCP, OV/EPS
SM12	POTABLE WATER TEST PORT
SM13	HYDROGEN SNIFFER PORT



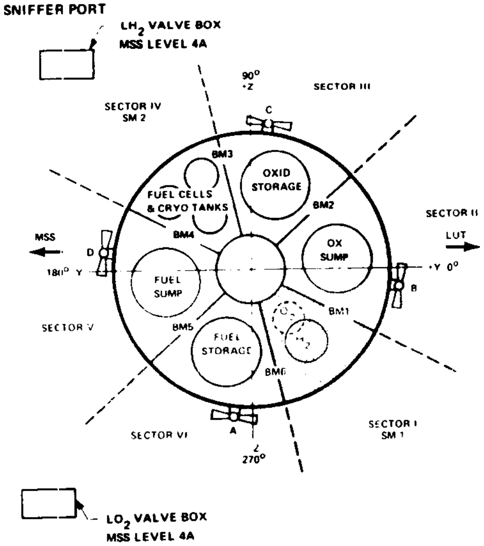


FIGURE 2 - S/C ACCESS DOOR AND TEST POINT (TP) LOCATIONS

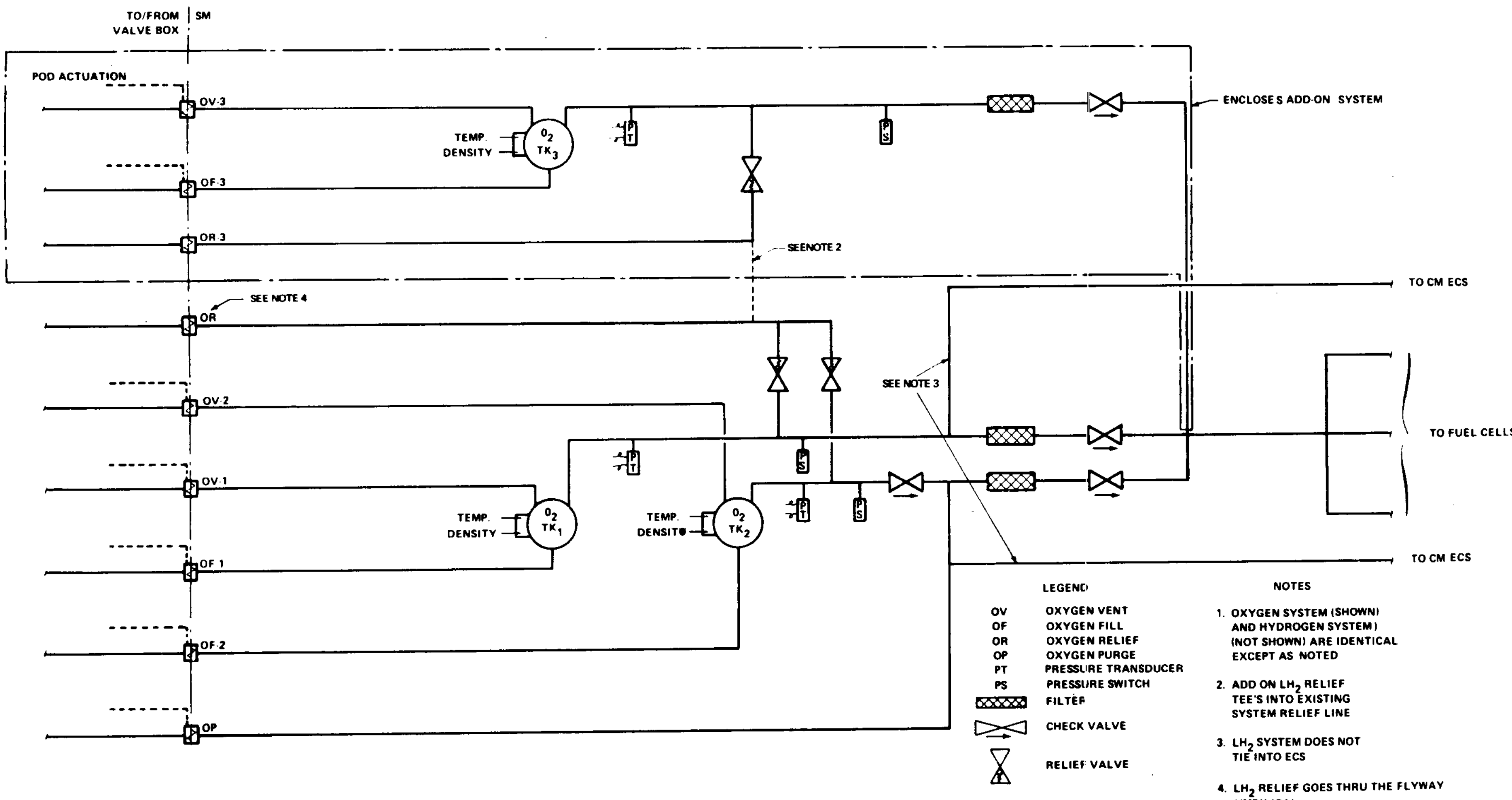


FIGURE 3- ALEM CSM EXPANDED CRYO SYSTEM

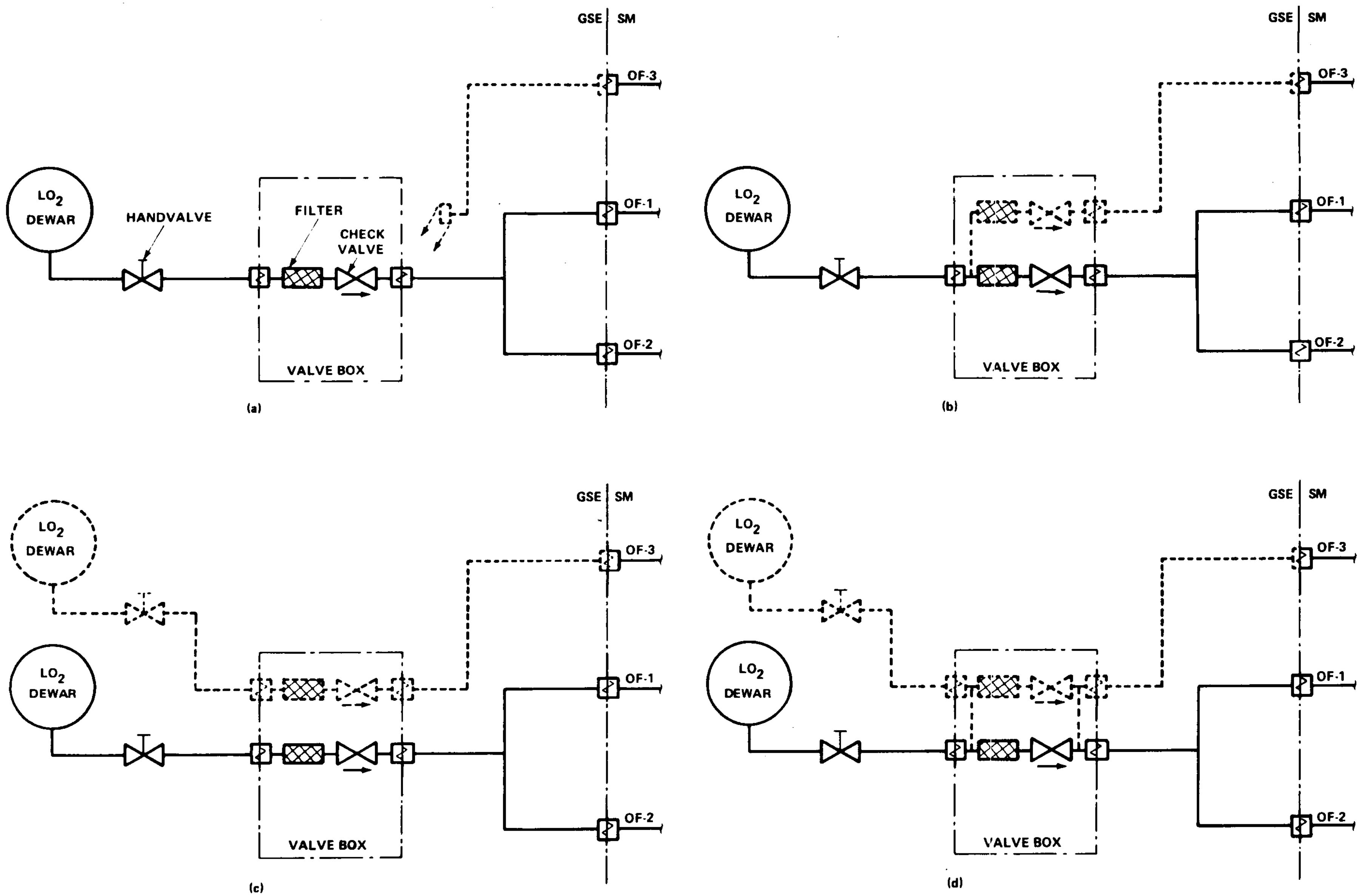


FIGURE 4 - CANDIDATE GSE SERVICING CONFIGURATIONS

TABLE 1

DEWAR AND SM CRYO STORAGE SYSTEM STATISTICS

	Lo_2	LH_2
DEWAR DRY WEIGHT	460 LBS	355 LBS
DEWAR LIQUID CAPACITY	1000 LBS	105 LBS
DEWAR WET WEIGHT	1460 LBS	460 LBS
BLOCK II CSM MISSION LOAD	670 LBS	60 LBS
LIQUID NEEDED TO ACHIEVE MISSION LOAD	$\approx$ 850 LBS	$\approx$ 90 LBS
ALEM CSM MISSION LOAD	1005 LBS	90 LBS
LIQUID NEEDED TO ACHIEVE ALEM CSM MISSION LOAD	$\approx$ 1275 LBS	$\approx$ 135 LBS
DUAL DEWAR LIQUID CAPACITY	2000 LBS	210 LBS
% DEWAR LOAD TO ACHIEVE ALEM CSM MISSION LOAD	$\approx$ 65 %	$\approx$ 65 %
$\approx$ WEIGHT OF DEWAR @ 65% LOAD	1110 LBS	423 LBS
TOTAL WEIGHT OF 2 DEWARS @65% LOAD	2220 LBS	846 LBS
ΔWEIGHT FOR MSS STRUCTURAL CONSIDERATION	760 LBS	N/A

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